

Innovation

HYDROGEN FROM RNG

Jeff Reed, SoCalGas

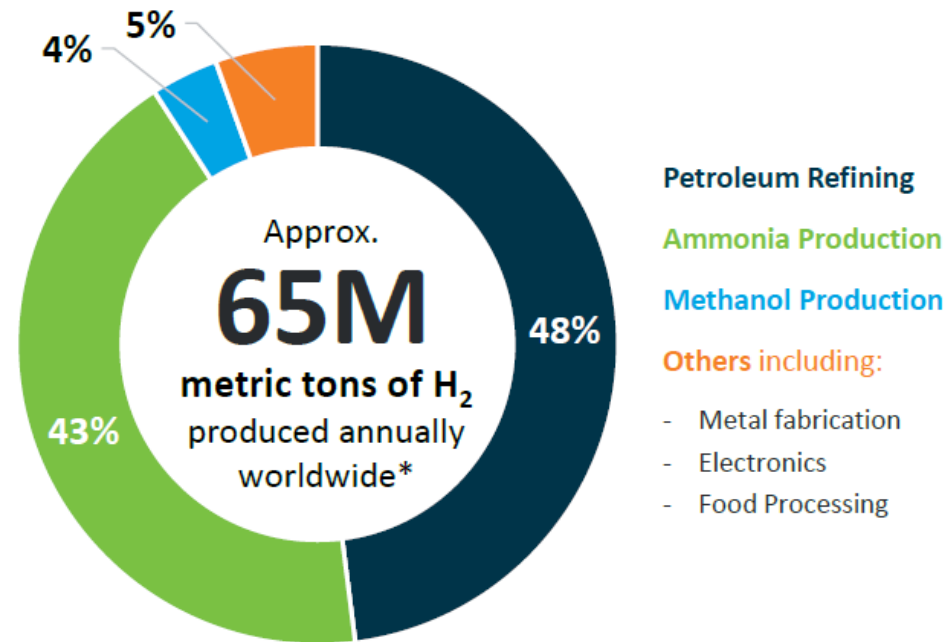
Current State of Hydrogen Production and Demand

Centralized H₂ Production Facilities in the U.S.



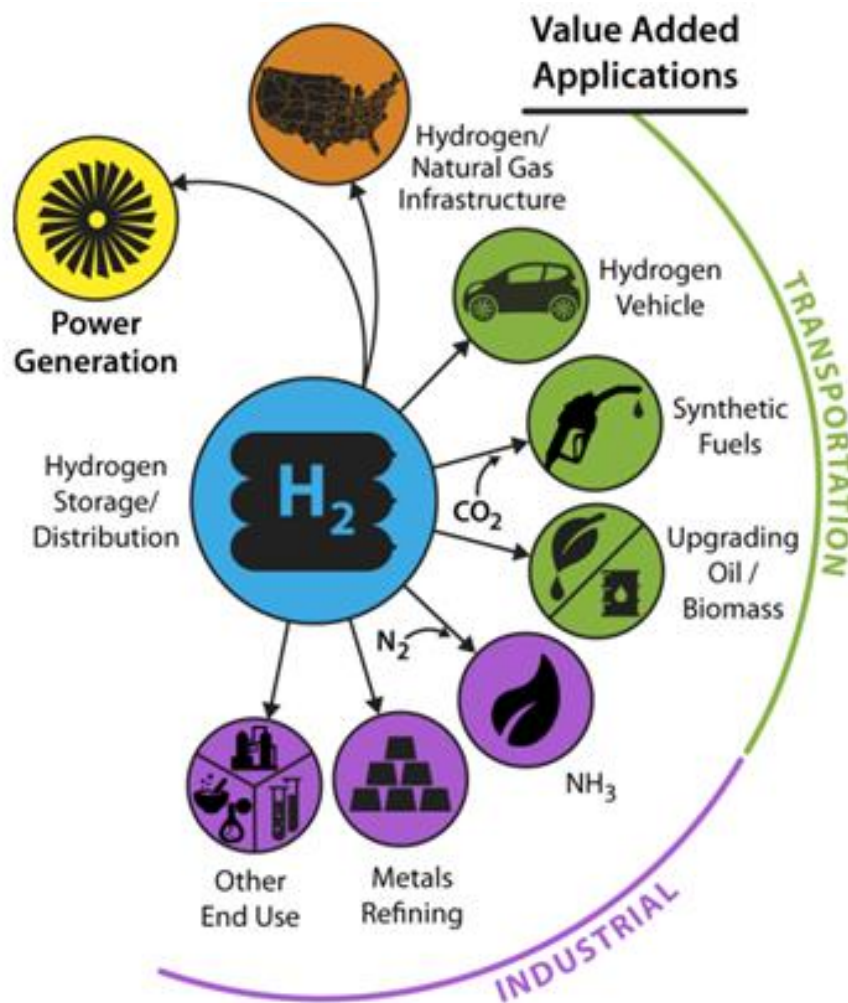
Source: NREL

Global Annual H₂ Production and Demand



Source: Markets and Markets. Hydrogen Generation Market: Global Trends & Forecasts to 2019, 2014.

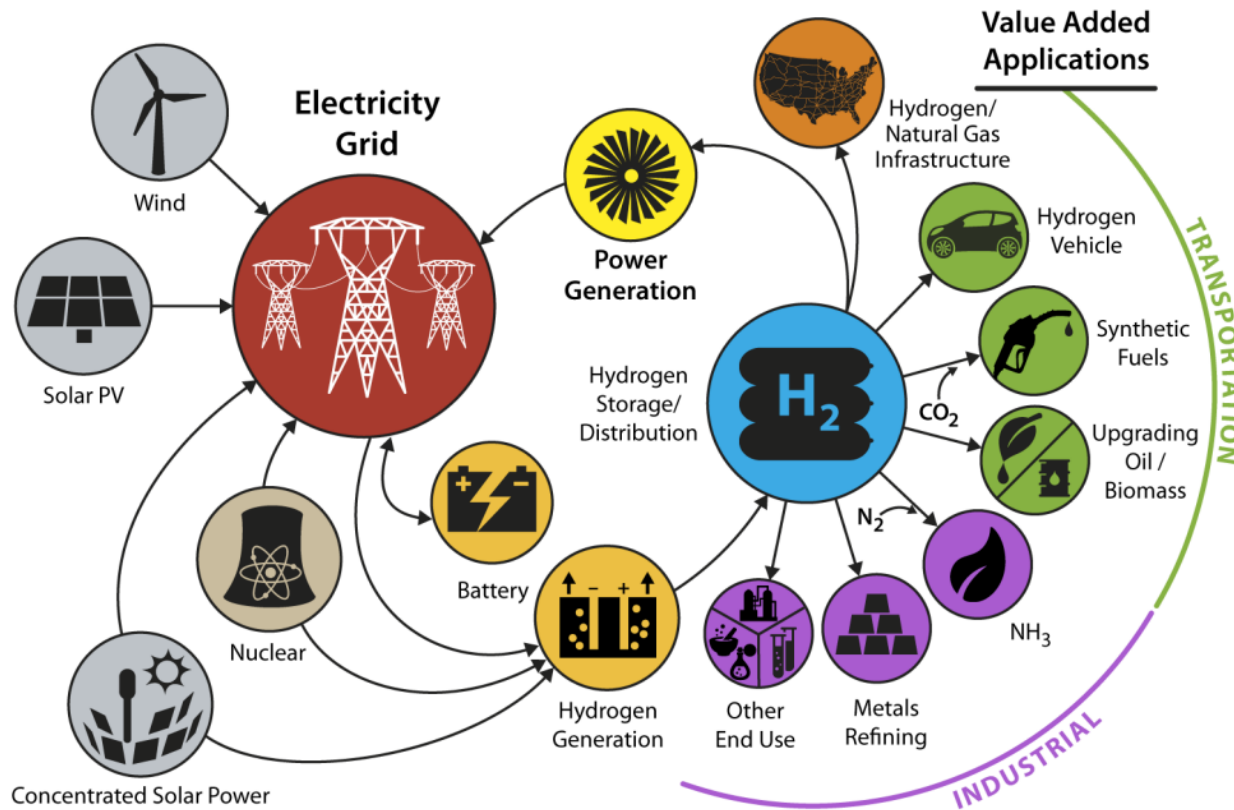
Multiple Market Segments to Consider



- » Petroleum Refining and Ammonia Production currently make up 91% of demand
- » Hydrogen vehicle market is small but shows signs of potential growth

GOVERNMENT AND POLICY DRIVERS

DOE Support for Hydrogen Economy



DOE's H2@Scale Energy System Vision

ENERGY.GOV
Office of Energy Efficiency & Renewable Energy

Fuel Cell Technologies Office

Energy Department Announces \$15.8 Million Investment for Innovation in Hydrogen and Fuel Cell Technologies

Today, the U.S. Department of Energy (DOE) announced approximately \$15.8 million for 30 new projects aimed at discovery and development of novel, low-cost materials necessary for hydrogen production and storage and for fuel cells onboard light-duty vehicles. Selected projects will leverage national lab consortia launched under DOE's [Energy Materials Network](#) (EMN) this past year, in support of DOE's materials research and advanced manufacturing priorities.

ARB Policies Support Hydrogen FCEV Deployment

» ARB 2017 Scoping Plan

- Recommends policies to achieve 100% ZEV* sales
- Proposes to electrify transportation using batteries AND hydrogen
- Promotes deployment of low carbon fuels including RNG and renewable hydrogen

» ARB 2016 Mobile Source Strategy

- 1.5 million ZEVs and Plug-in Hybrids by 2025
- 4.2 million ZEVs by 2030

* Zero Emission Vehicle – Includes Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEVs)

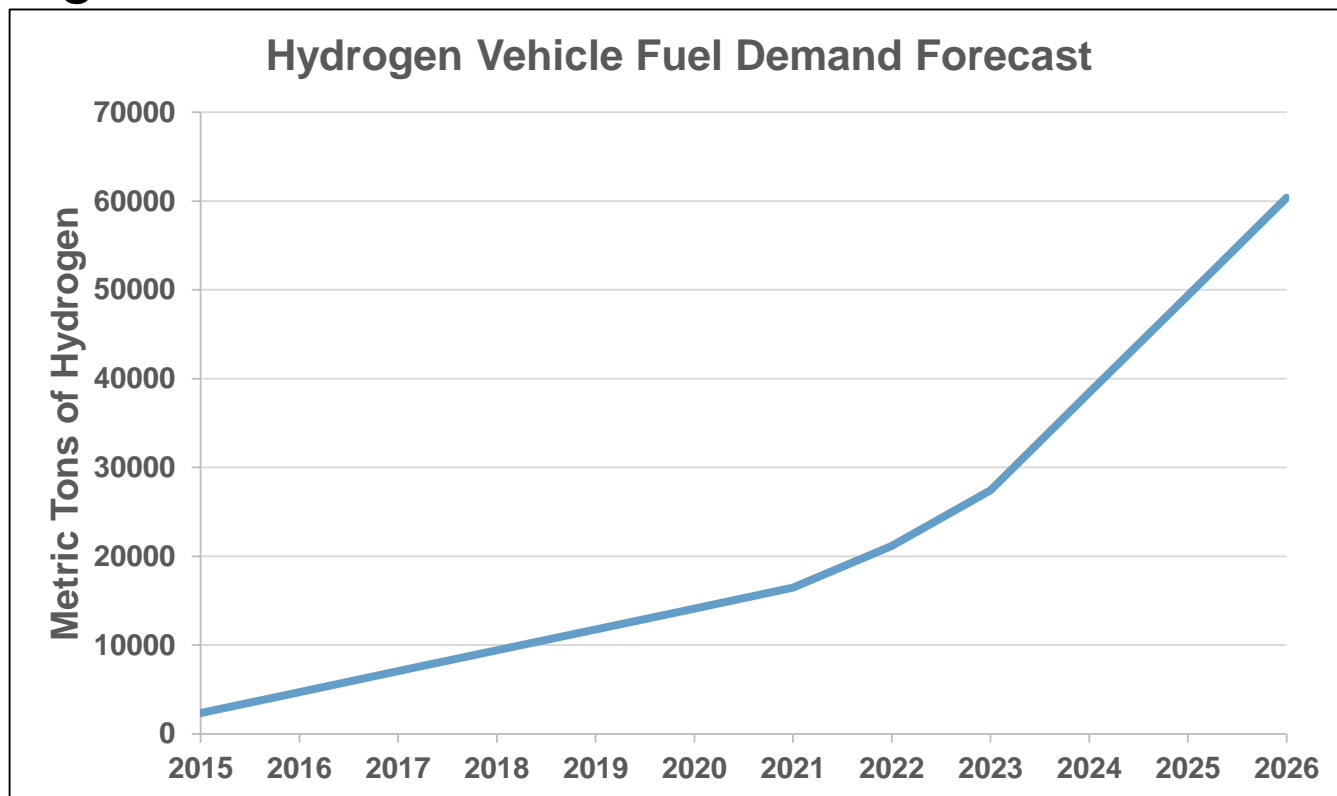
ARB Forecasts Increased FCEV Deployment

» ARB 2016 ZEV Report

- California FCEVs:
 - 13,500 in 2019
 - 43,600 in 2022
- California Hydrogen Fueling Stations:
 - 38 in service by the end of 2016
 - 50 in service by the end of 2017
- ARB predicts a hydrogen fueling capacity shortfall in 2020

CEC Forecasts Increased Hydrogen Demand

- » CEC Transportation Energy Demand Forecast
 - High Alternative Fuel Vehicle Scenario:



SB 1505 Requires Hydrogen from Renewable Sources

- » Well-to-Wheels GHGs from hydrogen use for vehicles must be 30% below the average for gasoline
- » All hydrogen produced for FCEVs must be made from at least 33.3% renewable energy resources
- » Immediately enforceable only for State funded stations
- » Privately funded stations are exempt until 3,500 metric tons (3.5 million kg) of hydrogen are sold in the state (Estimated in 2019)
- » Hydrogen fuel dispensed in California is expected to contain on average 45% renewably-sourced hydrogen (2016)

Source: 2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

PIPELINE RNG TO RH2 APPROACHES

Pipeline-to-Station + On-site Reformation

- » The current dominant approach to H₂ production is reformation $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$
- » System are optimized for large production volumes and are centralized
- » Product is trucked to point of use (or, in limited cases, piped over dedicated H₂ pipelines)
- » Small scale reformers are being developed to convert CH₄ to H₂ at point of use

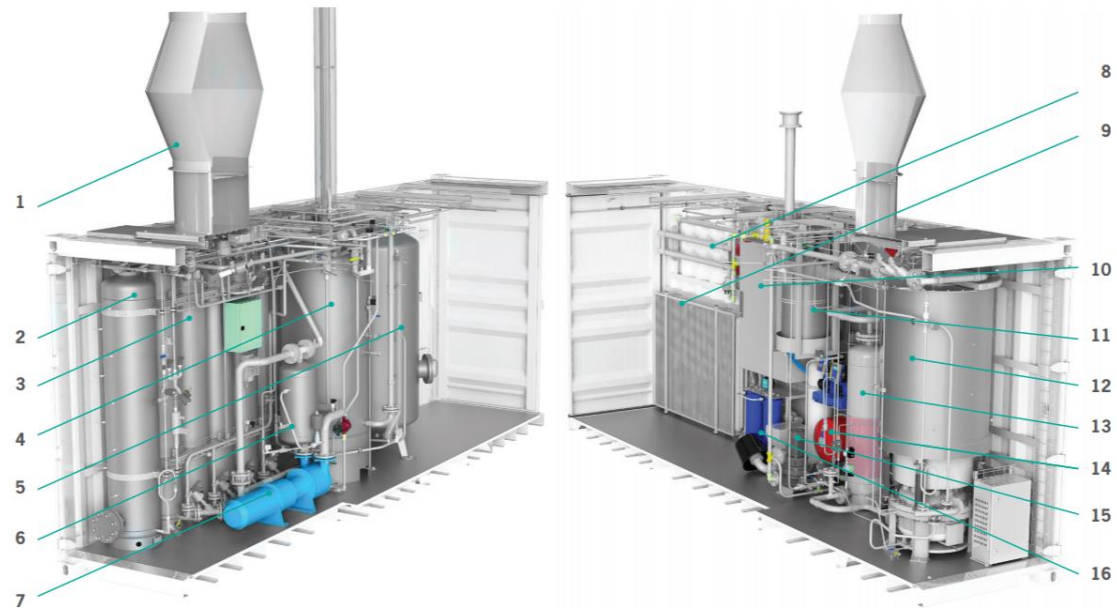
Current Technology

Small-scale Steam Methane Reforming (SMR)

3 Step SMR Process

- » *Reforming* – Endothermic catalytic reaction, High pressure (300-400 psi), High temp (1500-1600°F)

$$\text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + \text{H}_2$$
- » *Shift Conversion* – Exothermic catalytic reaction, possibly in 2 steps:
 - High temperature shift: 650-750°F
 - Low temperature shift: 450°F
$$\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$$
- » *Gas purification* – Remove CO_2 by amine scrub or pressure swing absorption



- | | | | |
|----------------------------|------------------------------------|-------------------------|-------------------------------|
| 1. Ventilation fan | 5. Hydrogen storage | 9. Reformate cooler | 13. Low temperature shift |
| 2. Desulphurisation vessel | 6. Water separator for vacuum pump | 10. Electronics cabinet | 14. Coolant expansion vessel |
| 3. PSA-vessels | 7. Vacuum pump | 11. Steam generator | 15. Burner air blower |
| 4. Off-gas storage | 8. Coolant heater | 12. Reformer unit | 16. Water purification system |

The HY.GEN small scale SMR unit fits in a standard shipping container.

Advanced Technology Distributed Solar SMR

Project

- Develop and demonstrate a Solar Thermochemical Advanced Reactor System (STARS) that converts methane and water into hydrogen and byproducts such as methanol and plastics.

Objectives

- Design, fabricate and test the next version of solar thermochemical system at the SDSU Brawley Test Site.
- Produce hydrogen at a rate of 25 kg/day.
- Demonstrate a solar-to-chemical energy conversion efficiency of greater than 75% (>20% renewable energy content).
- Provide adequate data for commercialization, manufacturing and operational schemes.
- Prepare for commercial pilot fueling station installation

Accomplishments

- Designed and fabricated the TRL 6 reactor.
- Began on-sun testing at SDSU Brawley.



A STARS test system deployed at SDSU
Brawley



Pacific Northwest
NATIONAL LABORATORY



Advanced Technology Compact Plasma SMR

Project

- Develop catalytic nonthermal plasma (CNTP) technology to efficiently produce hydrogen on an as-needed basis for distributed hydrogen generation from natural gas and water.

Objectives

- Conversion efficiency: > 75%
- Startup time: < 30 minutes
- Subscale unit production capacity: ~ 1Kg H₂/day
- Production Cost: \$ 2-4 gge H₂

Accomplishments

- Designed and fabricated a bench scale CNTP reactor.
- Demonstrated the feasibility of CNTP technology: 8 hrs, 450°C, 90% CH₄ conversion
- Optimized operating parameters CNTP reactor for H₂ production.
- Designed, fabricated and operated scaled-up 2kg H₂/day reactor. Tested steady-state and pulsed plasma.
- Demonstrated technical/engineering feasibility of CNTP H₂ production



Plasma visible during demonstration of the CNTP reformer.



Distributed H₂ production and fueling concept

Another Approach -- TriGen

